Final Technical Report

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Title: Systems Research for Remote Sensing Ocean Surface Circulation Using SeaSat-A Spacecraft

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The proposal itself sought to develop satellite-based remote sensing techniques for synoptic monitoring of ocean circulation. It was desired to use radar altimetry techniques in order to avoid the use of local ground truth measurements which are subject to uncertainties due to upward circulation.

Four reports resulted from this investigation:

1. On Vertical Datum Definition from GEOS-3 Altimetry (presented at the Second International Symposium on Problems Related to the Redefinition of North American Geodetic Networks Washington, D.C. April, 1978)

2. Determination of Some Dominant Parameters of the Global Dynamic Sea Surface Topography from GEOS-3 Altimetry (NASA Technical Memorandum 79558)

3. The Analysis of Temporal Variations in Regional Models of the Sargasso Sea From GEOS-3 Altimetry (NASA Technical Memorandum 79549)

4. The Shape of Global Mean Sea Level from GEOS-3 Altimetry (submitted to Nature).

The abstracts of the first three reports above (the other is itself a short note) outline quite clearly the nature and extent of the progress under this grant, and they are given below.

1. ABSTRACT. The serious doubts about the reliability of continental first order levelling networks prompts the development of new techniques for independently estimating the height of MSL at tide gauge sites. Techniques are described for achieving these goals from satellite altimetry. The problems to be overcome are illustrated by a study of numerical results obtained from the 1977 GEOS-3 altimetry data bank and the gravity anomaly files for Australia and central North America. The results indicate that gravity anomalies in these regions are compatible with the altimeter-defined geoid to $\pm$0.1mGal. It also provides an exacting test for the value of GM.

2. ABSTRACT: Gradients of the sea surface topography (SST) - i.e., heights of the sea surface in relation to the geoid - are essential for the real-time modelling of ocean dynamics. Ocean current measurements indicate the existence of SST gradients as large as $\pm$0.1 m per 10^2 km. A prerequisite for remote sensing SST from satellits is a geoid model with <u>at least</u> $\pm$6 cm resolution through equivalent wavelengths.

The only potential source of such data is a satellite-determined gravity field model. The internal statistics of the best such model available at present (GEM 9) indicate that favourable signal-to-noise exists for the recovery of the dominant parameters of the quasi-stationary dynamic sea surface topography from GEOS-3 altimetry.

The 1977 altimetry data bank available at Goddard is analyzed for the geometrical shape of the sea surface expressed as surface spherical harmonics after referral to the higher reference model defined by GEM 9. The resulting determination is expressed as quasi-stationary dynamic SST. Solutions are obtained from different sets of long arcs in the GEOS-3 altimeter data bank as well as from sub-sets related to the September 1975 and March 1976 equinoxes assembled with a view to minimizing seasonal effects.

The results obtained are compared with equivalent parameters obtained from the hydrostatic analysis of sporadic temperature, pressure and salinity measurements of the oceans and the known major steady state current systems with comparable wavelengths.

The most clearly defined parameter (the zonal harmonic of degree 2) is obtained with an uncertainty of ± 6 cm. The preferred numerical value obtained (-43cm) is smaller than the oceanographic value (-46) largely due to the effect of the correction for the permanent Earth tide. Similar precision is achieved for the zonal harmonic of degree 3. The precision obtained for the fourth degree zonal harmonic reflects more closely the accuracy expected from the level of noise in the orbital solutions, being a factor of 3 inferior to the values quoted above.

Attempts to obtain the harmonics $\int_{s111}$ and $\int_{s110}$ were not successful because of the masking effort of the non-geocentricity of the system of reference used. The dominant effect is southward displacement of 1.5m along the polar axis.

The results presented in this paper are preliminary. While some further progress of a limited nature may be forthcoming with improvements in the definition of orbits, the most important requirement for significant advances in remote sensing surface ocean dynamics using altimeter data, is the refinement of low degree tesseral harmonics of the satellite-determined gravity field model to 2 parts in 10^9.

3. ABSTRACT: The dense coverage of short pulse mode GEOS-3 altimeter data in the western North Atlantic provides a basis for studying time variations in the sea surface heights in the Sargasso Sea. Two techniques are utilized in this study:

- the method of regional models; and
- the analysis of overlapping passes.

Monthly models of the Sargasso Sea are produced for the period July to November 1975 and from April to August 1976. The analysis of the heights of common 0.2^o x 0.2^o squares indicates a root mean square (rms) discrepancy of $\pm$43 cm in values produced from different solutions. Approximately one quarter of this due to the variation in

geoid slope across 0.2° squares. The residual discrepancy is due to instabilities introduced by variable pass geometry, unmodelled ocean tides and meoscale variations in sea surface topography. Shortwave maxima and minima in the regional sea surface models are examined for correlations with surface and remote sense infrared temperature data. On allowing for differences in the quantities being compared, an 88 percent correlation is obtained between the location of cyclonic eddies obtained from infrared imagery and reported by the National Weather Service, and sea surface height minima in the altimeter models. This figure drops to 59 percent in the case of correlations with maxima and minima of surface temperature fields.

The analysis of overlapping passes provides a better picture of instantaneous sea state through wavelengths greater than 30 km. The resolution obtained is significantly higher ($\pm$33 cm on average) through the areal representation is limited to 32 selected profiles. Correlation studies with cyclonic and anti-cyclonic ocean eddies from the NIMBUS 6 and GEOS I and II infrared imagery indicate satisfactory agreement being obtained with equivalent sea surface height features 98 percent of the time if time varying factors are allowed for. The spectral analysis of the overlapping passes shows once again the high relative precision of the GEOS-3 altimeter in the short pulse mode. The variability of the Sargasso Sea through wavelengths between 150 km and 5000 km is estimated at $\pm$28 cm. On considering the magnitude

of unmodelled orbital error this value is in reasonable agreement with oceanographic estimates and is compatible with the eddy kinetic energy of a wind drive circulation.

An approximate estimation technique shows that the quasi-stationary SST maintaining the Gulf Stream is present in the GEOS-3 data but cannot be estimated with confidence in the absence of an adequate geiodal mode.

This completes the Final Technical Report. All reports are on file with:

NASA Scientific and Technical Information Facility
Baltimore/Washington International Airport
Baltimore, Maryland 21240

References

1. Mather, R. S., and C. Rizos, 1978, On vertical datum definition from GEOS-3 altimetry, Second International Symposium on Problems Related to the Redefinition of North American Geodetic Networks, Washington, D.C. April 1978, 10p.

2. Mather, R. C., F. J. Lerch, C. Rizos, E. G. Masters, and B. Hirsch, 1978, Determination of Some Dominant Parameters of Global Dynamic Sea Surface Topography from GEOS-3 Altimetry, NASA Technical Memorandum 79558, 40p.

3. Mather, R. S., R. Coleman, and B. Hirsch, 1978, The Analysis of Temporal Variations in Regional Models of the Sargasso Sea from GEOS-3 Altimetry, NASA Technical Memorandum 79549, 52p.

4. Mather, R. S. and C. Rizos, 1978, The Shape of global mean sea level from GEOS-3 altimetry, Submitted to Nature.